Ecosystem function and restoration in the Cache River Bioreserve, Illinois

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ABSTRACT

The main purpose of this grant was to give undergraduate students research experience via ongoing studies of cypress swamps in southern Illinois. The research was on a riverine system with altered hydrology, Buttonland Swamp, where sedimentation and protracted periods of inundation have the potential of disrupting the regeneration of cypress swamp species. To explore this idea, seed banks and seedlings from Buttonland Swamp were exposed to various levels of water depth and sedimentation. In the experiment, the highest number of seedlings germinated from seed banks which were not exposed to either inundation or sediments (58 seedlings m^{-2}). Seed germination was very limited by even low amounts of sediment (0.01-2 cm sediment depth). Cypress seedlings were limited more by water depth than by sedimentation. Survivorship of seedlings was reduced if overtopped by water (0% survivorship) but survived for the most part when exposed to sediment. However, if cypress seedlings were exposed to 15 cm of sediment under 10 cm of water or more, these died (0% survivorship). All experiments of seedlings conducted in the field failed either due to transplant shock or interference by raccoon. Overall these studies supported on-going studies showing that regeneration in Buttonland Swamp can only occur at the highest elevations of winter flooding. This research parallels the findings of other studies of forested wetlands with altered hydrology in the southeastern and western United States.

INTRODUCTION

Undergraduate Activities

The primary purpose of this grant was for the training of undergraduate students through their participation in the research related to ongoing studies of the relationship of cypress swamp regeneration to sedimentation and hydrology. Undergraduate students involved in the research activities this year including Melissa Rice, John Rivera, Jennifer Wright, Melanie Roffel, Terry Miller and Beth DeGrauwe. All of these students were involved in various aspects of the field and laboratory activities including the set up and monitoring of the seedling, soil and seed experiments. Melissa and Melanie also worked with data analysis via entering data and calculating means.

Sedimentation Studies

Sedimentation is a normal part of stream dynamics. Over time, stream meandering occurs in concert with sediment deposition patterns (Schumm 1969) and vegetation will colonize on these abandoned meanders (Shankman 1991; Shankman 1993; Shankman and Drake 1990; Shankman and Pugh 1992). In unaltered riverine systems, jams in the river created by woody debris and sediments can create new colonization sites for forest species on the downstream edge of new point bars in free-flowing rivers (Abbe and Montgomery 1996) and the new vegetation consequently influences geomorphological proceses in the stream (Gregory 1992).

However, around the world, sedimentation levels can be quite high where the stream channel has been altered by channelization (Brookes 1985; Regier *et al.* 1989; Sengupta 1995) or damming (Cairns and Palmer 1993; Hickin 1983; National Research Council 1992; Petts 1984; Shuman 1995), and also where land use practices in the region have shifted to agriculture (Karr and Schlosser 1977) or logging (Maki *et al.* 1975).

Study Site

Buttonland Swamp is a remnant swamp along the Lower Cache River near Perks, Illinois (Fig. 1; 37°17'50"N; 89°03'10"E). Before the alteration of the region by logging and agriculture (Wichmann 1996), much of southern Illinois was an extensive mosaic of cypress and mixed hardwood swamp of 250,000 hectares (Ugent *et al.* 1981).

Water flow patterns were greatly altered in Buttonland Swamp when water was diverted upstream from the Cache to the Ohio River via the Post Creek Cutoff in 1916, leaving only Cypress and Big Creek as water sources for the site (Demissie *et al.* 1990). In Buttonland Swamp, annual sediment deposition in 1963 ranged from 0.3-2.8 cm (Fig. 2; Demissie et al., 1990). The Diel Dam, a low channel-head dam was built in 1982 (Muir *et al.* 1995). Buttonland Swamp is now continuously impounded with regeneration of trees of cypress swamp species only in the zone between the highest elevation of the flood sheet and extended summer drawdown (Middleton 1995a).

The objective of the study (beyond the training of undergraduate students) was to examine the relative effects of sedimentation and water depth on seed germination and seedling establishment.

METHODS

Seed Banks, Sedimentation and Hydrology

In spring, 1996, soil was collected from random locations in Buttonland Swamp using a post hole digger from a canoe. The soil was transported to the greenhouse of the department of Plant Biology. Soil was evenly divided into 5 trays (30 x 30 cm) per treatment and then assigned to treatment blocks within tanks in the greenhouse. The treatment combinations included water depths of 0, 5, and 20 cm and sediment depths of 0, 0.01, 1 and 2 cm. Sterilized sediment was manufactured by pressure steaming swamp soil for several hours. Seedlings emerging from the seed bank were recorded for one year.

Seedlings, Sedimentation and Hydrology

Greenhouse Study

Seedlings were grown from seed and transplanted into pots in March 1996. Five seedlings were subjected to treatment combinations of three water depths including freely drained, flooded and overtopped by water (0, 10 and 20 cm, respectively) and sediment depths including 0, 7.5 and 15 cm of soil. The survival of the seedlings was followed for several months following the water and sediment treatments.

Field Study

In September 1996, seedlings in the field on the edge of Buttonland Swamp near Crawford Tract were selected for the study which were growing at a winter flood elevation. Seedlings in five blocks were treated with sediment in-situ by carefully surrounding them with a PVC pipe and filling the pipes to 3 sediment depths including 0, 7, 15 cm of soil. Seedlings were also monitored which were not surrounded by PVC pipes.

After 1 month, all of the PVC pipes had been knocked over by raccoon. The experiment was abandoned because we could not think of a way to keep the raccoon away from the PVC pipes without constructing a very large and obtrusive exclosure.

Note that in the previous fall (October 1995), another field experiment was attempted where we transplanted 5 replicate cypress seedlings at four elevations, and subjected them to either 0 or 7.5 cm of sediment burial. This study also failed because the seedlings succumbed to transplant shock. No seedling at any elevation revived after the winter. Some of the seedlings which had been subjected to sedimentation lived for several months. All of the seedlings placed underwater died within the first month.

FINDINGS

Seed Banks, Sediment and Water Depth

World-wide studies of wetland seed banks have demonstrated that the seeds of emergent and tree species typically do not germinate underwater (Fowell 1965; Leck 1996; Leck and Graveline 1979; Leck and Simpson 1987; Leck and Simpson 1995; Mattoon 1915; Middleton 1995a; Middleton 1995b; Middleton 1996; Middleton *et al.* 1991; Newling 1993; Parker and Leck 1985; Thompson 1992), so that drawdown is essential in the regeneration of species (Keddy and Reznicek 1986; Middleton 1995a; Middleton 1995b; Middleton 1996; van der Valk 1988; van der Valk and Davis 1978).

However, fewer studies have examined the role of sedimentation on seedling emergence from seed banks. Sedimentation reduced the number of seedlings emerging from the seed banks of freshwater wetlands in Alaska (van der Valk *et al.* 1983) and from along the Delaware River (Leck 1996). In general, the smaller the seed, the more readily it is affected by the depth of soil burial (Leck 1996).

In this study, the highest numbers of seedlings emerged if not treated with either sediment or inundation (58 seedlings m^{-2}; Figure 3). Seedling emergence from the seed bank was greatly reduced when submerged in any depth of water (< 3 seedlings m^{-2}). In the absence of water, sediment depth also reduced seedling emergence from the seed bank.

Seedlings, Sediment and Water Depth

Seedlings are a critical stage in the regeneration of emergent and tree species, and are slightly more flexible in their tolerance of water depth than seeds (Middleton 1996). Cypress seedlings typically can withstand periods of inundation, so long as the tips of the seedlings are emerged from the water column (Demaree 1932; Mattoon 1916). Most other species of bottomland hardwood forest tend not to be as tolerant of submergence (Dickson *et al.* 1965; Hosner and Boyce 1962; Whitlow and Harris 1979).

Very few studies of the effects of sedimentation and water depth on seedling survival have been conducted, though such studies are essential in the understanding the dynamics of tree regeneration in swamps. In this study, water at depths overtopping the seedlings killed the seedlings regardless of sediment depth (0% survival; Figure 4). However, in the deepest sediment treatment (15 cm), seedlings had a lower survival rate at all water depths (0-20 cm; 0-60% survival; Figure 4).

These greenhouse studies match the field observation that no regeneration of the tree species of cypress swamps is occurring in Buttonland Swamp below the elevation of permanent flooding. In the spring and summer, seeds germinate in the drawdown zone along the upper elevation of winter flooding (Middleton 1995a). Because the lower portions of this zone refloods during the growing season, cypress seedlings survive only at the highest elevations corresponding to the upper edge of the flood pulse (approximately 101.8785 m msl; Middleton, unpublished).

These findings are similar to those of other altered riverine systems in North America. Cypress swamps tend to regenerate only along the upper elevations of impounded swamps (Klimas 1987). Similarly, cottonwood forests regenerate only in a narrow band along rivers with altered hydrology in Montana (Scott *et al.* 1993a; Scott *et al.* 1993b). The hydrologic conditions imposed by flood pulsing is an essential component of regeneration in cypress swamps because of the narrow life history tolerances of seeds and seedlings (Middleton 1995a).

REFERENCES

Abbe, T. B., and Montgomery, D. R. 1996. Large woody debris jams, channel hydraulics and habitat formation in large rivers. Regulated Rivers: Research and Management, **12**: 201-221.

Brookes, A. 1985. River channelization: traditional engineering methods, physical consequences and alternative practices. Progress in Physical Geography, **9**: 44-73.

Cairns, J., Jr. , and Palmer, S. E. 1993. Senescent reservoirs and ecological restoration: an overdue reality check. Restoration Ecology, **1**: 212-219.

Demaree, D. 1932. Submerging experiments with *Taxodium*. Ecology, **13**: 258-262.

Demissie, M., Soong, T. W., Allgire, R., Keefer, L., and Makowski, P. 1990. Cache River basin: hydrology, hydraulics, and sediment transport. Volume I. Background, data collection, and analysis. Illinois State Water Survey, Champaign, Illinois.

Dickson, R. E., Hosner, J. F., and Hosley, N. W. 1965. The effects of four water regimes upon the growth of four bottomland tree species. Forest Science, **11**: 299-305.

Fowell, H. A. 1965. Silvics of Forest Trees of the United States. U.S. Department of Agriculture, Washington, D.C.

Gregory, K. J. 1992. Vegetation and river channel process interactions. *In* River conservation and management. *Edited by* P. J. Boon, P. Calow and G. E. Petts. Wiley, Chichester. pp. 255-269.

Hickin, E. J. 1983. River channel changes: retrospect and prospect. *In* Modern and Ancient Fluvial Systems. *Edited by* J. D. Collinson and J. Lewin. vol. Special Publication #6 of the International Association of Sedimentologists. Blackwell Scientific Publications, Oxford, England. pp. 61-83.

Hosner, J. F., and Boyce, S. G. 1962. Tolerance to water saturated soil of various bottomland hardwoods. Forestry Science, **8**: 180-186.

Karr, J. R., and Schlosser, I. J. 1977. Impact of Nearstream Vegetation and Stream Morphology on Water Quality and Stream Biota. University of Illinois, Champaign, Illinois.

Keddy, P. A., and Reznicek, A. A. 1986. Great Lakes vegetation dynamics: the role of fluctuating water levels and buried seeds. Journal of Great Lakes Research, **12**: 25-36.

Klimas, C. V. 1987. Baldcypress response to increased water levels. Wetlands, **7**: 25-37.

Leck, M. A. 1996. Germination of macrophytes from a Delaware River tidal freshwater wetland. Bulletin of the Torrey Botanical Club, **123**: 48-67.

Leck, M. A., and Graveline, K. J. 1979. The seed bank of a freshwater tidal marsh. American Journal of Botany, **66**: 1006-1015.

Leck, M. A., and Simpson, R. L. 1987. Seed bank of a freshwater tidal wetland: turnover and relationship to vegetation change. American Journal of Botany, **74**: 360-370.

Leck, M. A., and Simpson, R. L. 1995. Ten-year seed bank and vegetation dynamics of a tidal freshwater marsh. American Journal of Botany, **82**: 1547-1557.

Maki, T. E., Hazel, D. W., and Weber, A. J. 1975. Effects of stream channelization on bottomland and swamp forest ecosystems. National Technical Information Service, Springfield, Virginia.

Mattoon, W. R. 1915. The Southern Cypress. United States Department of Agriculture, Washington, D.C.

Mattoon, W. R. 1916. Water requirements and growth of young cypress. In *Proceedings of the Society of American Foresters.* Society of American Foresters, Washington, D.C., pp. 192-197.

Middleton, B. A. 1995a. The Role of Flooding in Seed Dispersal: Restoration of Cypress Swamps along the Cache River, Illinois. U.S. Geological Survey and Water Resources Center, Champaign, Illinois.

Middleton, B. A. 1995b. Seed banks and species richness potential of coal slurry ponds reclaimed as wetlands. Restoration Ecology, **3**: 311-318.

Middleton, B. A. 1996. Characteristics of plants in forested wetlands. *In* Symposium Proceedings, Management of Forested Wetlands in the Central Hardwoods Region. *Edited by* S. D. Roberts and R. A. Rathfon. Purdue University, West Lafayette, Indiana.

Middleton, B. A., van der Valk, A. G., Davis, C. B., Mason, D. H., and Williams, R. L. 1991. Vegetation dynamics and seed banks of a monsoonal

wetland overgrown with *Paspalum distichum* in northern India. Aquatic Botany, **40**: 239-259.

Muir, D. B., Hite, R. L., King, M. M., and Matson, M. R. 1995. An Intensive Survey of Cache River Basin. EPA, Marion, Illinois.

National Research Council 1992. Restoration of Aquatic Ecosystems. National Academy Press, Washington, D.C.

Newling, C. J. 1993. Restoration of bottomland hardwood forests in the Lower Mississippi Valley. Restoration and Management Notes, **8**: 23-28.

Parker, V. T., and Leck, M. A. 1985. Relationships of seed banks to plant distribution patterns in a freshwater tidal wetland. American Journal of Botany, **72**: 161-174.

Petts, G. E. 1984. Impounded Rivers: Perspectives for Ecological Management. Wiley, Chichester.

Regier, H. A., Welcomme, R. L., Steedman, R. J., and Henderson, H. F. 1989. Rehabilitation of degraded river ecosystems. In *Proceedings of the International Large River Symposium* ed. D. P. Dodge. Canadian Special Publication of Fisheries and Aquatic Sciences 106, Honey Harbour, Ontario, pp. 86-97.

Schumm, S. A. 1969. River metamorphosis. In *Proceedings on the American Society of Civil Engineers, Journal of the Hydraulics Division, HY1*, pp. 255-273.

Scott, M. L., Auble, G. T., Friedman, J. M., Ishchinger, L. S., Eggleston, E. D., Wondzell, M. A., Shafroth, P. B., Bach, J. T., and Jordan, M. S. 1993a.

Flow Recommendations for Maintaining Riparian Vegetation along the Upper Missouri River, Montana. National Biological Survey, Fort Collins, Colorado.

Scott, M. L., Wondzell, M. A., and Auble, G. T. 1993b. Hydrograph characteristics relevant to the establishment and growth of western ripairan vegetation. In *Proceedings of the Thirteenth Annual American Geophysical Union Hydrology Days* ed. H. J. Morel-Seytoux. Hydrology Days Publications, Atherton, CA, pp. 237-245.

Sengupta, R. (1995). Fluvial sedimentology of Cypress Creek, Union, Johnson, and Pulaski Counties, southern Illinois. M.S. thesis, Southern Illinois University.

Shankman, D. 1991. Forest regeneration on abandoned meanders of a Coastal Plain river in western Tennessee. Castanea, **56**: 157-167.

Shankman, D. 1993. Channel migration and vegetation patterns in the southeastern coastal plain. Conservation Biology, **7**: 176-183.

Shankman, D., and Drake, L. G. 1990. Channel migration and regeneration of bald cypress in western Tennessee. Physical Geography, **11**: 343-352.

Shankman, D., and Pugh, T. B. 1992. Discharge response to channelization of a coastal plain stream. Wetlands, **12**: 157-162.

Shuman, J. R. 1995. Environmental considerations for assessing dam removal alternative for river restoration. Regulated Rivers: Research and Management, **11**: 249-261.

Thompson, K. 1992. The functional ecology of seed banks. *In* Seeds: The Ecology of Regeneration in Plant Communties. *Edited by* M. Fenner. CAB International, Southampton, England. pp. 231-258.

Ugent, D., Tindall, D. R., and Doorenbos, N. J. 1981. Big trees of the southern Illinois Cache River bottoms. Phytologia, **47**: 420-440.

van der Valk, A. G. 1988. From community ecology to vegetation management: providing a scientific basis for management. Transactions of the 53rd North American Wildlife and Natural Resources Conference, : 463-470.

van der Valk, A. G., and Davis, C. B. 1978. The role of seed banks in the vegetation dynamics of prairie glacial marshes. Ecology, **59**: 322-335.

van der Valk, A. G., Swanson, S. D., and Nuss, R. F. 1983. The response of plant species to burial in three types of Alaskan wetlands. Canadian Journal of Botany, **61**: 1150-1164.

Whitlow, T. H., and Harris, R. W. 1979. Flood Tolerance in Plants: A State-of the-art Review. U.S. Army Corps of Engineers, Vicksburg, Mississippi.

Wichmann, R. F. 1996. A natural history of the Cache River watershed. M.S. thesis, Southern Illinois University.

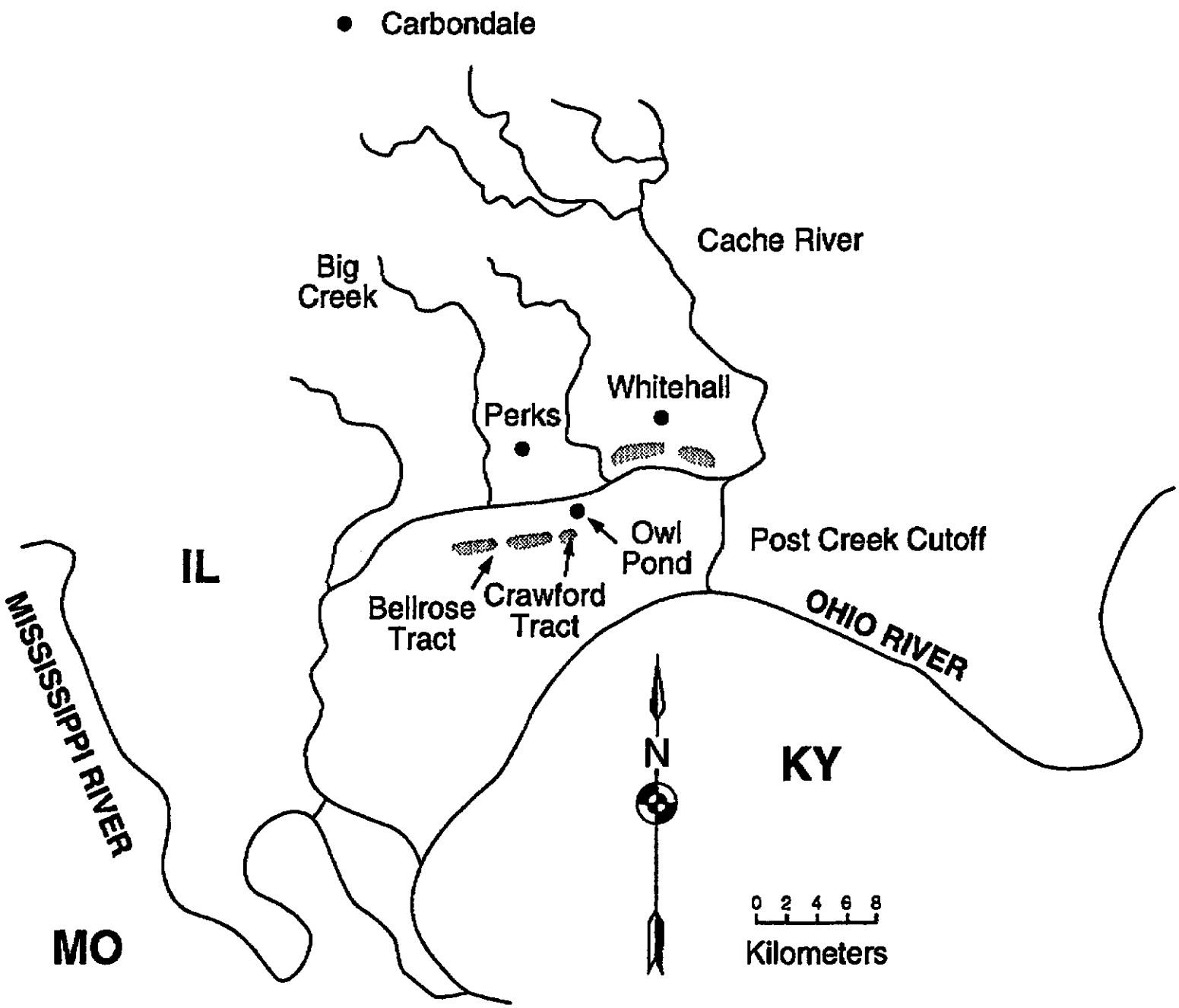
Figure Captions

Figure 1. Location of Crawford Tract in Buttonland Swamp near Perks, Illinois.

Figure 2. Sedimentation rates in Buttonland Swamp in 1963 (redrawn from Demissie et al., 1992).

Figure 3. Seedling emergence m^{-2} from the seed banks of Buttonland Swamp exposed to various sediment (0, 0.01, 1, 2 cm) and water depths (0, 5, 20 cm) in the Plant Biology greenhouse, Southern Illinois University at Carbondale.

Figure 4. Cypress seedling survival following sedimentation (0, 7.5 and 15 cm) and submergence (freely drained, flooded and overtopped; 0, 10 and 20 cm, respectively). Study conducted in the Plant Biology greenhouse, Southern Illinois University, March 1996-March 1997.



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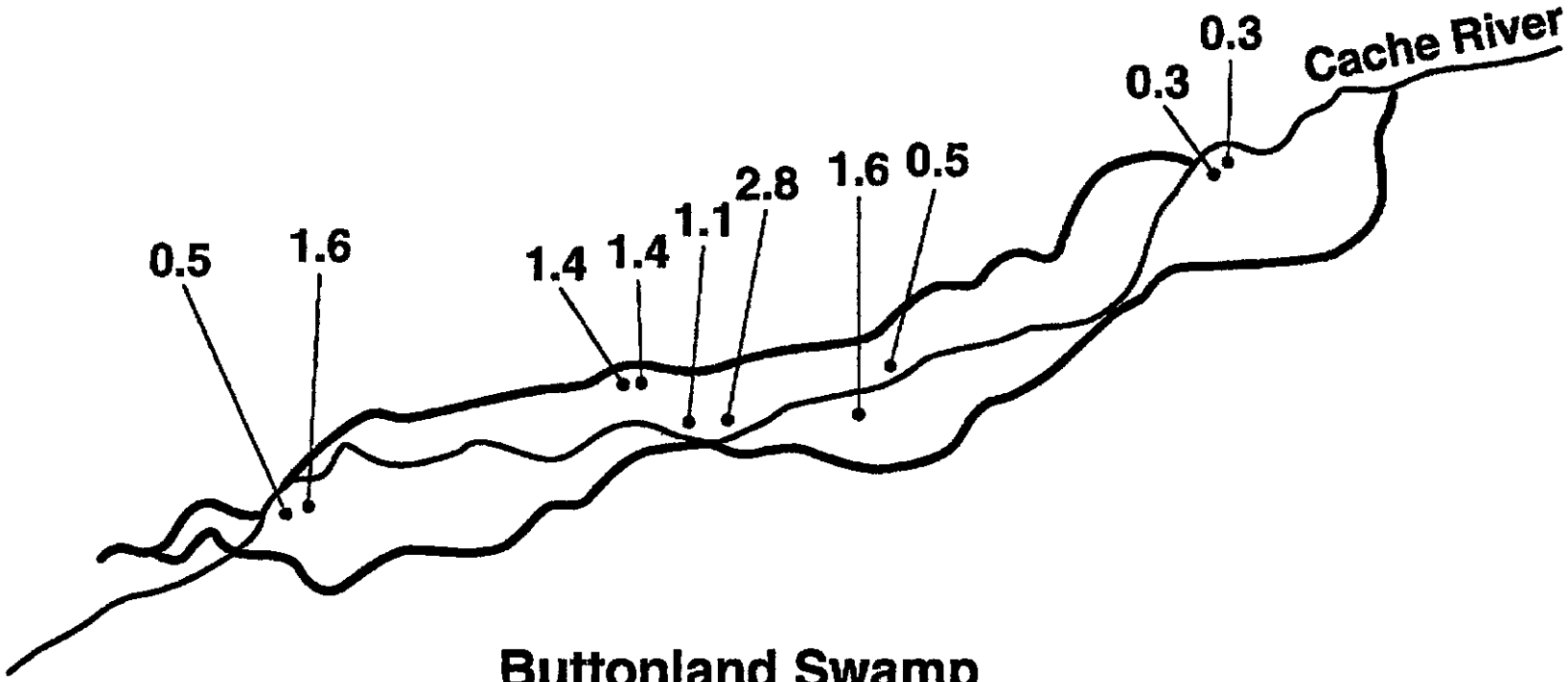
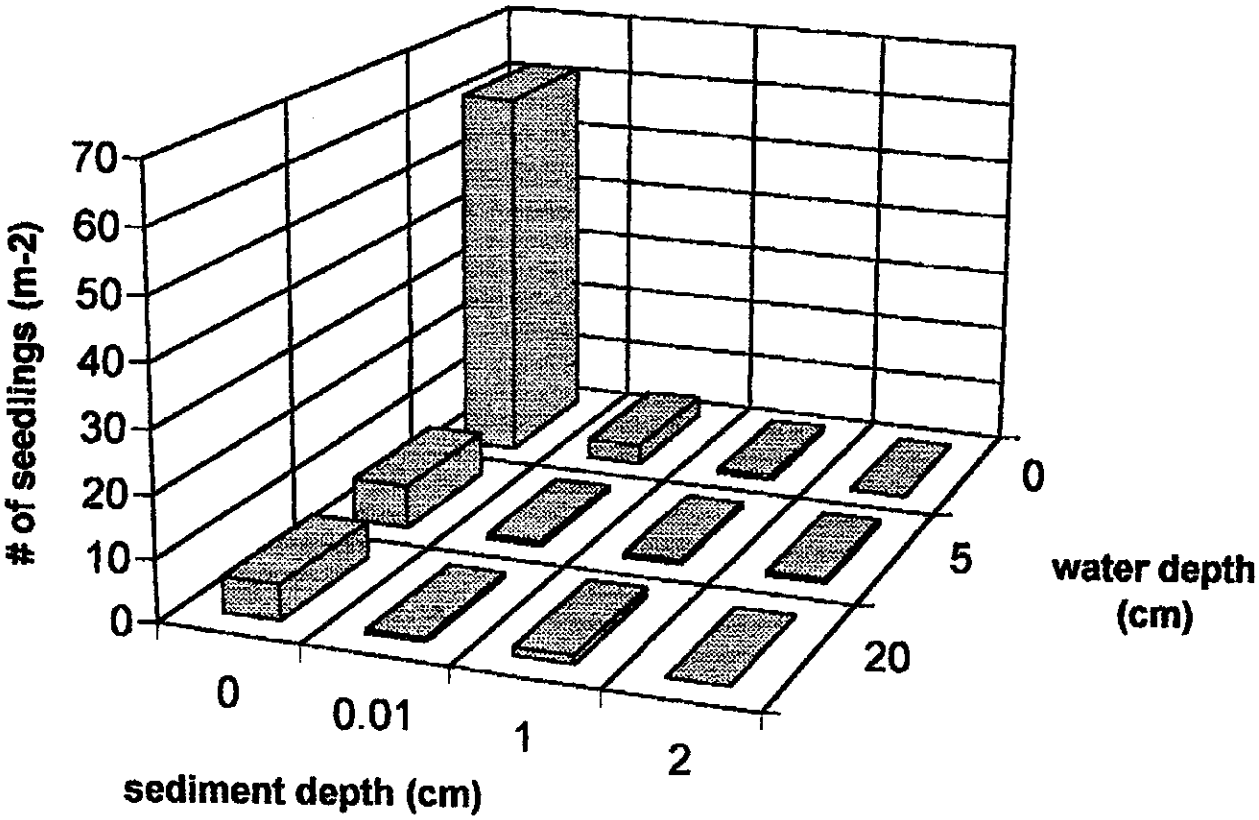
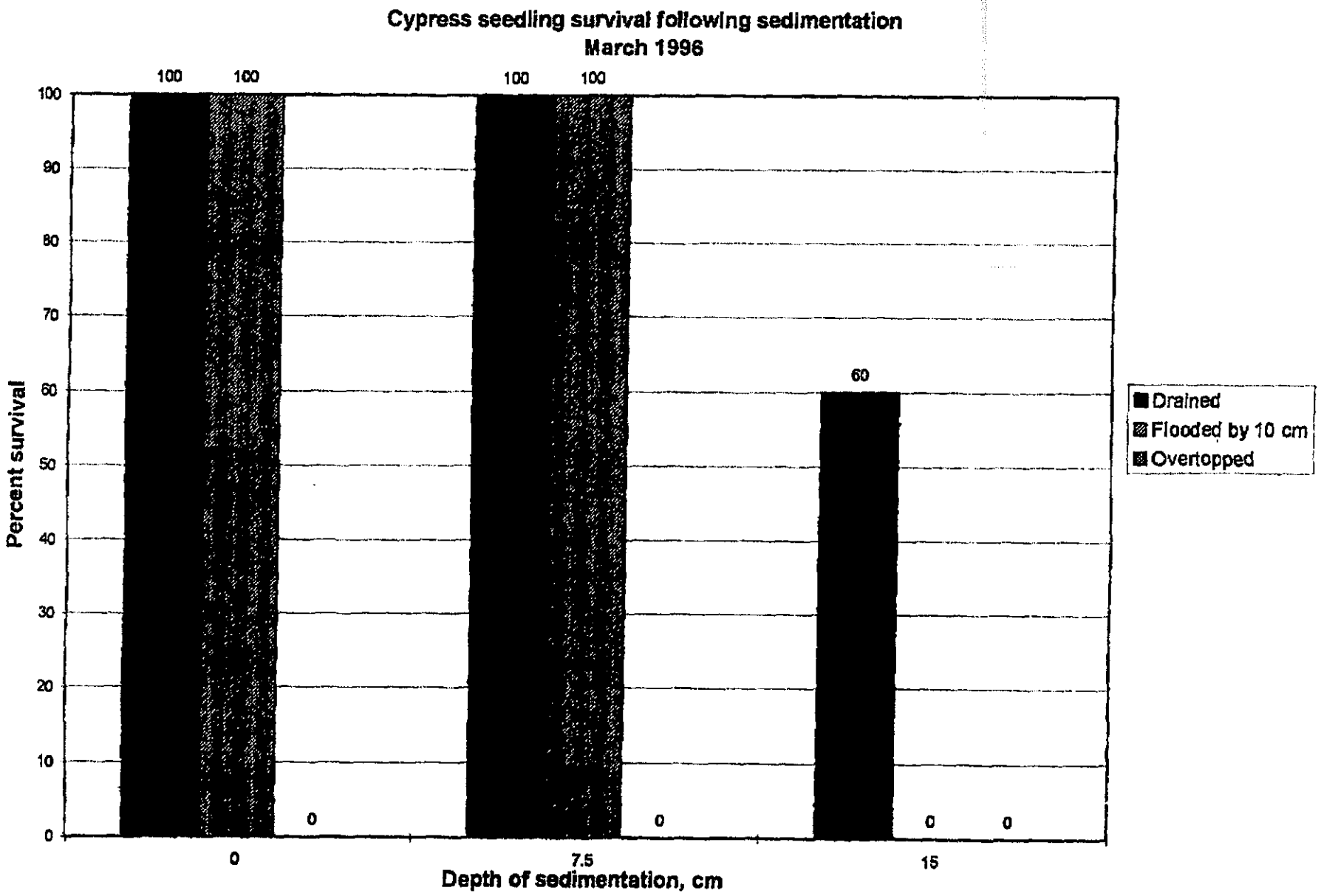
1963 Sedimentary Rate cm yr^{-1}
(from Demissie *et al.* 1992)



Buttonland Swamp

Seedling emergence: sedimentation and water depth




Cypress seedling survival following sedimentation
March 1996
Percent survival
100
90
80
70
60
50
40
30
20
10
0
100
100
0
100
100
0
60
0
0
0
7.5
15
Depth of sedimentation, cm
Drained
Flooded by 10 cm
Overtopped